MULTI-CRITERIA ANALYSIS FOR THE SELECTION OF LOCATION FOR DISTRIBUTION CENTER USING ANALYTICAL HIERARCHY PROCESS

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Abstract: *The selection of right location of the Distribution Centers (DC) for the pharmaceutical is an important issue. Analytical Hierarchy Process (AHP), a Multi-Criteria Decision Making (MCDM) tool is used in present research to evaluate important factors related to DC location and select most appropriate location for DC. Linguistic variables were used to assess the ratings and the weights for quantitative or qualitative factors. Four significant criteria and their sub-criteria were identified based on previous literature and expert opinions to compare seven alternative locations in Rajshahi Division of Bangladesh. The pair wise comparison matrix regarding criteria, sub-criteria and alternatives was formed by quantifying all data collected by survey based questionnaire. Consistencies of all matrices were checked and the level of inconsistency was in the acceptable range. Analyzing the collected data Bogra was selected as best suited location for DC.*
Key-words: AHP, Distribution center, Multi-Criteria Decision Making, Location factors, Consistency index.
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1. Introduction

Distribution center (DC) is defined as a structure that is primarily used for the receipt, temporary storage, possible customization and distribution of

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goods that are redirected from production sites to where they are consumed (wikipedia, 2012). Distribution is the key driver of the overall profitability of a firm because it affects both supply chain cost and customer experience. Therefore, appropriate location selection for DC is important to achieve a variety of supply chain objectives ranging from low cost to high responsiveness (Javaheri et al., 2006).

The purposes of best location for the DC are to increase the responsiveness as well as to save the freight transportation cost. Location problems involve the determination of the location of one or more new facilities in one or several potential sites. Location selection is a Multi-Criteria Decision Making (MCDM) problem that includes both tangible and intangible factors (Kahraman et al., 2003). The majority of research approaches for location selection focus on heuristics (Tavakkoli-Moghaddam et al.) and mathematical programming, such as integer programming (Melkote and Daskin, 2001), dynamic programming (Canal et al., 2001), and nonlinear programming (Nanthavanij and Yenradee, 1999). Moreover, the decision makers do not contribute in decision making process, and the role of experience is ignored. Another problem is appeared when there are a lot of alternatives.

Analytical Hierarchy Process (AHP), a MCDM tool enables to structure a complex problem into a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic way. The goal of this research is to provide decision-makers a scientific method to choose appropriate location for distribution center. Moreover, the practical considerations are reflected over the current study adopting AHP where weightings for the decision factors of a qualitative nature were introduced.

2. Application of AHP

AHP, developed in (Saaty, 2000) is used to solve complex decision-making problems in different areas, such as planning (Kwak and Lee, 2002), evaluating (Jaber and Mohsen, 2001) and allocating (Alphonce, 1997) resources, measuring performance (Frei and Harker, 1998), choosing the best policy after finding a set of alternatives (Poh and Ang, 1999), setting priorities (Schniederjans and Wilson, 1991) etc.

AHP is a popular method to find a solution to the problem of location selection. Tzeng et al. (2002) tried to find the best location for a restaurant planned to be built in the city of Taipei using AHP among the available alternative locations based on eleven selected criteria.

Viswanadham et al. (1999) developed a generic framework that can aid decision makers in identifying and grouping the *M* attributes into a hierarchy for location selection in global supply chains. A hierarchical structuring was proposed with four fundamental factors: product/process value chain, economic and political integration, resources and management, and connecting technologies.

Javaheri et al. (2006) performed a study involving a kind of multi factors evaluation method under the name of weighted linear combination by using geographical information technology as a practical instrument to evaluate the suitability of the vicinity of Giroft city in Kerman province of Iran for landfill using AHP. Water permeability, slope, distance from rivers, depth of underground water level, distance from residential areas, distance from generation centers, general environmental criterion and distance from roads were considered as the influencing factors in the process of analysis.

Korpela and Tuominen (1996) presented an integrated approach for the warehouse site selection process to enable smooth and efficient transportation facilities, where both quantitative and qualitative aspects were considered. Thus, AHP has the flexibility to combine quantitative and qualitative factors, to handle different groups of factors, to combine the opinions expressed by many experts, and can help in stakeholder analysis.

3. Materials and methods

3.1. AHP model

AHP approach categorizes a decision problem into several levels and thus uses a hierarchic structure in order to define the problem. In this approach, each element existing in the hierarchy is assumed to be independent of one another (Kong and Allan, 2007). The employed AHP model in this research consists of several steps as shown in figure no.1.

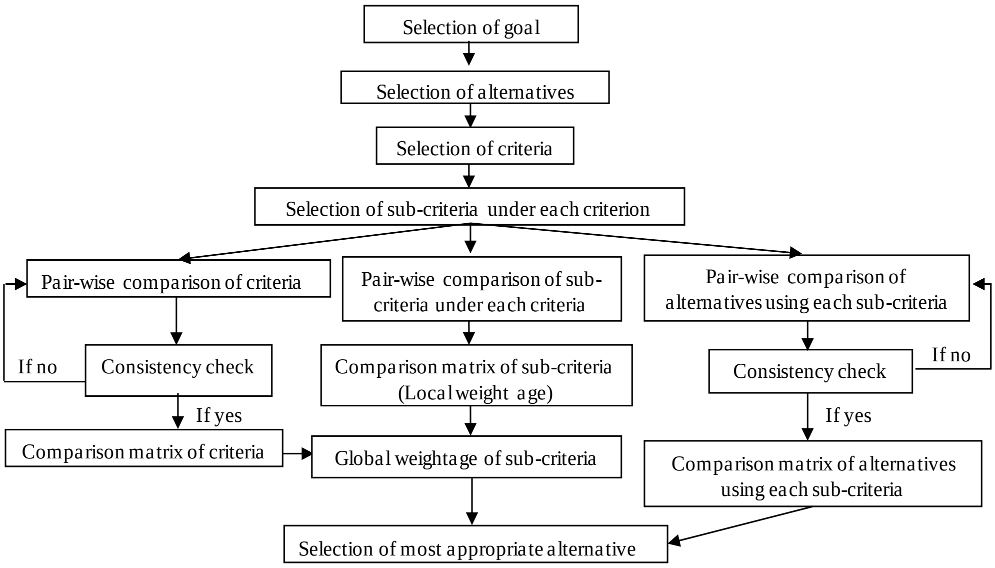

Figure no.1. Steps for applying AHP model

It starts with setting the goal followed by selection of alternatives. Practical judgment is necessary for the step of criteria selection. Then each criterion is categorized into sub-criteria. Pair-wise comparisons are required in three stages: i) among criteria ii) among sub-criteria and ii) among alternatives using each sub-criterion. These comparisons are made using Saaty's (1990) discrete 9 value scale as presented in table no.1.

Table no.1

Saaty's (1990) discrete 9 value scale of relative importance

Numerical value (*i*)	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Absolute importance
2,4,6,8	Intermediate values between two adjoining judgments.
1/*i*	Inverse importance

A hypothetical comparison of three alternatives A_1, A_2 and A_3 using single criterion C_1 is shown in table no.2.

Table no.2

A hypothetical comparison table

	A_1	**A_2**	**A_3**
A_1	**1**	**P**	**Q**
A_2	**1/P**	**1**	**R**
A_3	**1/Q**	**1/R**	**1**

Table no.2 can be transferred into $n \times n$ pair-wise comparison matrix, A_w.

$$A_w = \begin{bmatrix} 1 & p & q \\ 1/p & 1 & r \\ 1/q & 1/r & 1 \end{bmatrix}$$

The relative weights of A_1, A_2 and A_3 can be determined from matrix A by normalizing it into a new matrix (say, N_w). This process requires dividing the elements of each column by the sum of the elements of the same column. The desired relative weights of three alternatives are then computed as row average of the new matrix.

3.2. Consistency check

The columns of A are identical, means the decision maker exhibits perfect consistency in specifying the entries of the comparison matrix A. Mathematically, the matrix A is consistence if

$$a_{ij}.\ a_{jk} = a_{ik} \text{ for all values of i, j and k.}$$

It is abnormal for all comparisons to be consistence. A reasonable level of inconsistency is expected and tolerated due to the nature of human judgment. To determine whether or not, the level of inconsistency is ‘reasonable’, Saaty (1990) developed a methodology as: estimation of the Consistency Index (CI) using equation 1.

$$CI = \frac{\lambda_{\max} - n}{n-1} \qquad (1)$$

here, *n* is the size of matrix (n × n) and λ_{max} can be defined as the product of A_w and N_w. Consistency Ratio (CR) can be estimated using equation 2. As a rule of thumb, if CR value is equal or less than 0.10, the pair-wise comparison results are accepted; otherwise, these should be rejected and revised.

$$CR = \frac{CI}{RC} \qquad (2)$$

The Random Consistency (RC) of the matrix A can be estimated using table no.3.

Table no.3

The Random Consistency (RC) for various matrix size (n)

n	1	2	3	4	5	6	7	8	9
RC	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Source: Triantaphyllou and Mann, 1995

3.3. Ranking of alternatives

The final step of AHP application starts giving the weights of alternatives. It can be executed by multiplying the alternative decision matrix with criteria judgment matrix as:

$$\text{Weights of alternatives} = \begin{bmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ C_x & C_y & C_z \end{bmatrix} * \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

Where, A, B, C are the three possible alternatives and x, y, z are three selection criteria

4. AHP for the selection of distribution center location

4.1. Alternatives

AHP is a popular method used to find a solution to the problem of MCDM. One of the reasons for the popularity of AHP as an applicable method is the fact that it takes into consideration not only the tangible but also the intangible criteria. For instance, determining the best location for a distribution center is a problem that involves both many numerical and non-numerical criteria. Therefore, AHP method seems to be an easily applicable method in finding a solution to the problem of exactly where to build a DC.

In setting up the DC, seven alternative locations are considered as probable choices. The layout of these locations is shown in figure no.2.

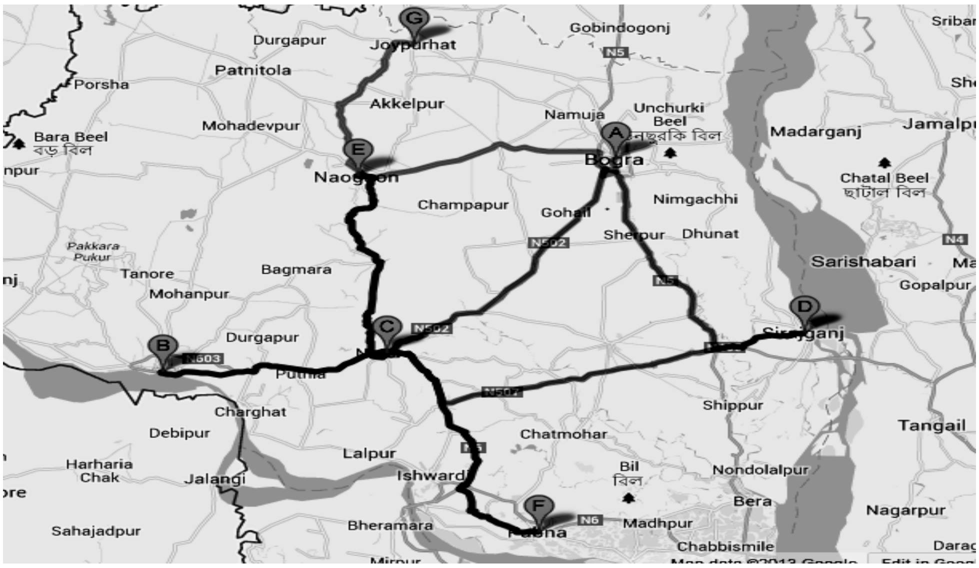

Figure no.2. The geographical location of seven alternative locations

4.2. Decision criteria

Determination of criteria requires one to be an expert, assuming the fact that wrong or inadequate determination will end in financial losses. The opinions of experts should be sought for particularly complex problems because it is vital to define the criteria to be followed. Through extensive literature review and performing pilot survey among academic and professional experts some factors were initially identified as shown in figure no.3. From all of the initially identified factors a detailed prioritization was performed for further categorization into sub-criteria. Finally four main criteria were identified and three of them were sub categorized into two sub-criterias. The factor electricity was not sub categorized as the alternative locations for the DC are in the same region.

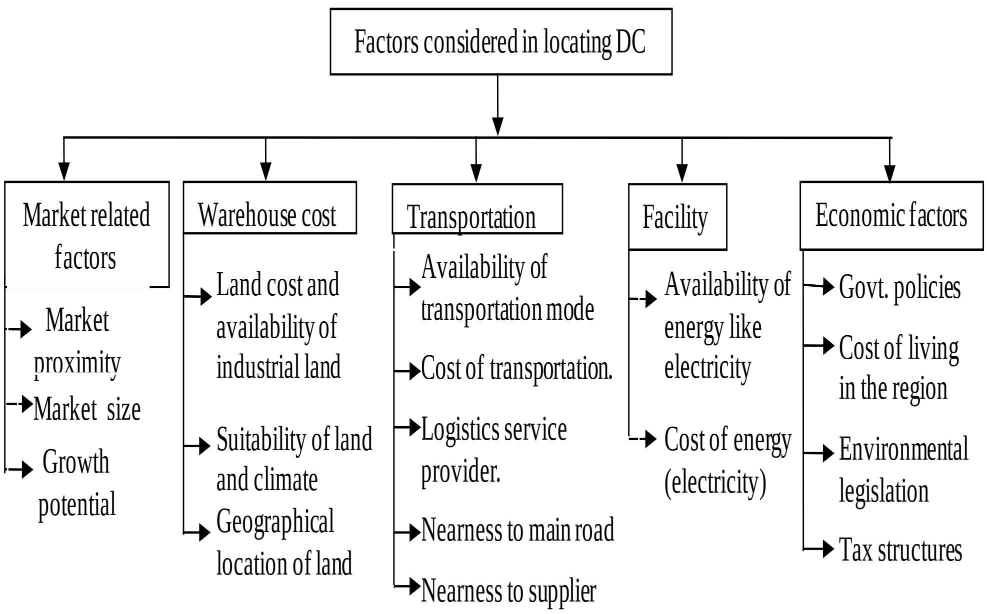

Figure no.3. Available factors considered in locating a distribution center

The final hierarchy of the problem with the goal, alternative locations and the selected factors along with the code (as defined in table no.4) is shown in figure no.4.

Table no. 4

Definition of code name of typical factors and sub-factors

Definition	Code name
Criteria	
Market factors	C_m
Warehouse cost	C_w
Transportation	C_t
Availability of electricity	C_{ae}
Sub-criteria	
Market proximity	C_{mp}
Market size	C_{ms}
Land cost	C_l
Suitability of land	C_{sl}
Availability of transport	C_{at}
Cost of transportation	C_{ct}

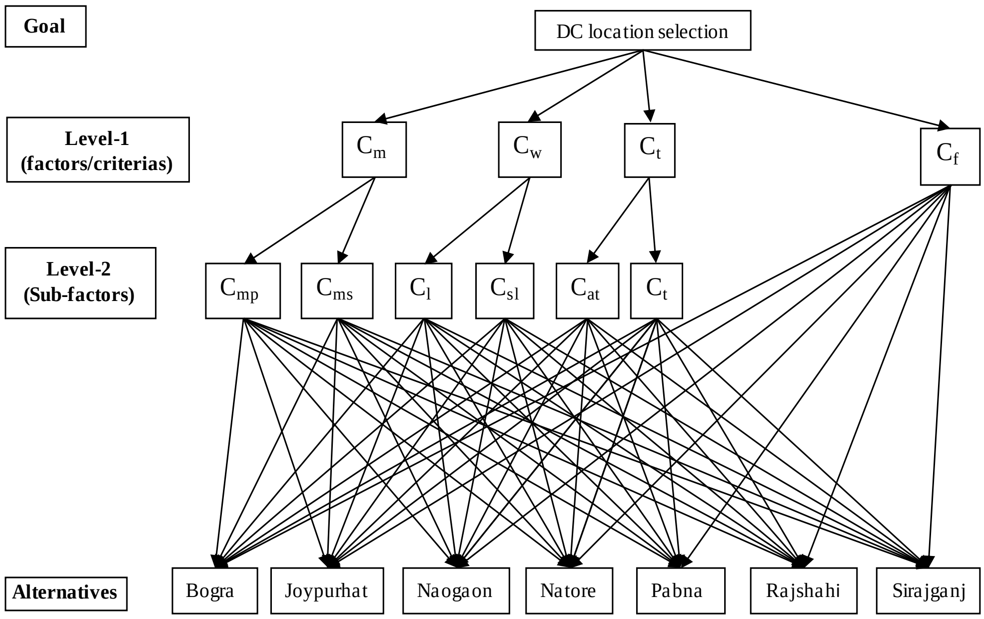

Figure no.4. Proposed AHP model for performance matrixes hierarchy.

In selecting the location, market related factors are one of the most important evaluation criteria and it is important to increase the market share. The sub-criteria of the market related factors are proximity to market and market size. The distance from distribution center to the market where the drug is supplied is defined as proximity to market. Smaller distance saves the carrying cost as well as reduces the response time. The number of buyers and sellers in a particular market is called market size. This is also defined by the number of population to be served.

Warehouse cost is another important criterion. The elements of warehouse cost are land cost and suitability of industrial land. Not all lands are of equal value, nor the required lands are available everywhere. The amount someone is willing to pay for a piece of property is known as land value, and it ebbs and flows with the economy and current land market.

Third main criteria were transportation including availability of transportation mode and cost of transportation. As can be seen in figure no.4, facility criteria i.e., availability of electricity has no sub-criteria at all.

5. Results and discussion

For developing comparison matrices at first a survey questionnaire was prepared for:

- Each sub-criteria taking each main criterion into consideration;
- Each main criterion taking the goal to be achieved into consideration;
- Each alternative taking each sub-criterion into consideration.

After collecting data from thirty four experts those data were sorted, arranged and the required matrices were formed. A comparison matrix for criteria is shown in table no.5, obtained by taking geometric mean (Escober et al., 2004) of all 34 experts' data.

Table no. 5

Comparison matrix for Major Criteria

	Market factors	Warehouse cost	Transportation	Availability of electricity
Market factors	1.000	3.445	2.752	4.144
Warehouse cost	0.290	1.000	0.923	1.754
Transportation	0.367	1.118	1.000	2.168
Availability of electricity	0.241	0.570	0.468	1.000
Column sum	1.899	6.134	5.144	9.067
	CI=0.0133	RI=0.99	CR=0.013434	

Geometric mean was used because all values are none zero value. The consistencies of the matrices were also checked and it was found that the level of inconsistency is in the acceptable range as described in (Taha, 2007).

The second stage of analysis is to calculate relative weights of sub-criteria. For this purpose a 2×2 reciprocal matrix is formed using pair wise comparison as number of sub-criteria considered was two. The columns of any 2×2 comparison matrix are dependent and hence a 2×2 matrix is always consistent as mentioned in (Taha, 2007). Comparison matrix for sub-criteria of market factors is shown in table no.6 and correspondingly weightage of all sub-criteria were calculated.

Table no.6

Comparison matrix for sub- criteria of market factor

	Market proximity	Market size
Market proximity	1.000	1.033
Market size	0.968	1.000
Column sum	1.968	2.033

Final relative weights of main criteria and sub-criteria those were considered in the determination of a suitable location for a DC are calculated and presented in figure 5.

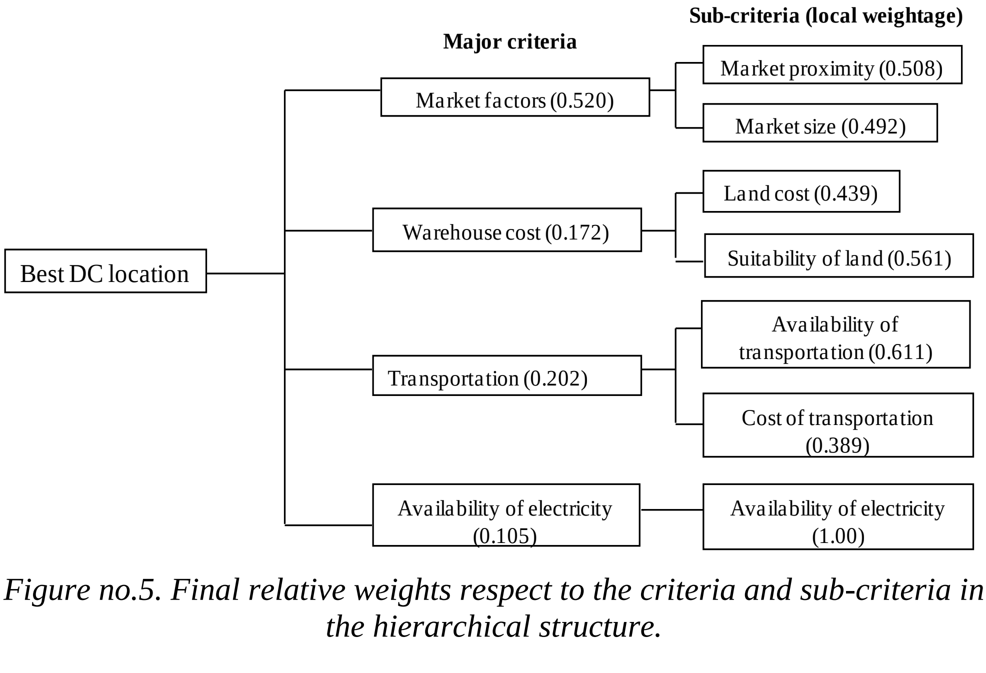

Figure no.5. Final relative weights respect to the criteria and sub-criteria in the hierarchical structure.

Table no. 7

Ranking of criteria according to their weight

Sub-criteria	Global weight	Ranking
Market proximity	0.264	1
Market size	0.256	2
Availability of transportation	0.124	3
Availability of electricity	0.105	4
Suitability of land	0.097	5
Cost of transportation	0.079	6
Land cost	0.076	7
Column sum	1.000	

Like the sub-criteria "proximity to market" the comparison matrix for other criteria was formulated and relative weight of alternatives locations according to the sub-criteria is presented in table no.9.

Table no. 8

Final alternatives' comparison matrix on basis of "proximity to market"

	Bogra	Joypurhat	Naogaon	Natore	Pabna	Rajshahi	Sirajgonj
Bogra	1.000	6.216	1.251	0.372	5.858	4.827	4.323
Joypurhat	0.196	1.000	0.200	0.177	0.855	0.330	0.811
Naogaon	0.826	4.558	1.000	0.428	4.934	4.261	5.238
Natore	2.687	5.643	2.334	1.000	6.029	4.219	4.082
Pabna	0.171	1.169	0.203	0.168	1.000	0.240	0.937
Rajshahi	0.207	3.032	0.235	0.237	3.982	1.000	3.782
Sirajgonj	0.231	1.232	0.191	0.245	1.067	0.264	1.000
Column sum	5.317	22.850	5.413	2.627	23.726	15.141	20.174
		CI=0.10	RI=1.41	CR=0.02			

The overall decision was calculated by the equation:

Final weight =Σ [Factor's global weight * alternative's weight according to that factor]   (3)

Based on equation 3 the calculation for alternative Bogra is shown.

Bogra = (0.264×0.228) + (0.256×0.268) + (0.124×0.081) + (0.105×0.317)+ (0.097×0.331) + (0.079×0.237) + (0.076×0.321) = 0.259.

Table no. 9

Final Relative Weight of Alternative Locations according to the factors

	Market proximity	Market size	Land cost	Suitability of land	Availability of transportation	Cost of transportation	Availability of electricity
Bogra	0.228	0.268	0.081	0.317	0.331	0.237	0.321
Joypurhat	0.040	0.027	0.165	0.076	0.064	0.038	0.066
Naogaon	0.202	0.128	0.034	0.053	0.055	0.041	0.055
Natore	0.338	0.051	0.038	0.150	0.166	0.194	0.138
Pabna	0.040	0.072	0.161	0.099	0.097	0.100	0.100
Rajshahi	0.103	0.147	0.372	0.260	0.221	0.110	0.261
Sirajganj	0.048	0.307	0.149	0.045	0.065	0.280	0.058

Calculating the weightage of all seven locations the ranking of these locations are arranged in a descending order as shown in table no.10.

Table no. 10

Ranking of Locations

Location	Final weight
Bogra	0.259
Rajshahi	0.182
Natore	0.170
Sirajganj	0.143
Naogaon	0.110
Pabna	0.081
Joypurhat	0.055

Conclusions

It has been proved that MCDM tool like AHP is a useful scientific tool for decision making. From the obtained results following conclusions can be drawn:

- Among all the available alternatives 'Bogra' is the best suited location for establishing the distribution center.
- Market proximity is the most prominent sub-criteria for comparing the available alternative locations.

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